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WILLIAM LASSELL, Esq., F.R.S., President, in the Chair.

Josh. H. Freeman, Esq., Stratford House, Stratford;  
R. Holford M. Bosanquet, Esq., St. John's College, Cam-  
bridge; and

Harry Taylor, Esq., Avenue Road, Regent's Park,

were balloted for and duly elected Fellows of the Society.

*Note on the Construction of the Heavens, explanatory of a Chart of 324,198 Stars.* By Richard A. Proctor, B.A. (Cambridge).

It is well known that, according to the theory of the universe enunciated by Sir W. Herschel in 1785,—that theory which is commonly, but erroneously, described as the outcome of his labours amid the star-depths,—the stars visible to the unaided eye are included within a space which bears an exceedingly minute proportion to the dimensions of the Galaxy itself. Herschel's original drawing of a section of the Galaxy—as conceived by him in 1785—is before me as I write. It extends across a folding sheet in a quarto volume. On the same scale, he says, the distance of the nearest fixed star would be no more than the 80th part of an inch, “so that probably all the stars which in the finest nights we are able to distinguish with the naked eye may be comprehended within a sphere,” in the middle of this picture of our Galaxy, “*of less than half a quarter of an inch radius.*”

It was with reference to this view that in a paper called

“Notes on Star Streams,” which appeared in the *Intellectual Observer* for August 1867, I pointed out that the stars of the first five orders of magnitude, only, show too marked a tendency to follow the direction of that great star-stream, the Milky Way, for the flat-disk theory to be admissible. I then noted,—and I am careful to mention the point, because objections have been urged which would imply that I had forgotten it,—that the first five orders of stars could give but very imperfect evidence if the accepted views about star distribution were just. But “it is on on that very fact,” I added, “that I wish to dwell. If any connexion *does* appear between the configuration of our Galaxy, and the arrangement of stars which are assumed to be much nearer to us than the Milky Way, it will be obvious that we must somewhat modify our views.”

I was not then aware that the astronomer Piazzì had noted the same fact,—though he had dealt rather with statistical evidence than with the more direct evidence I adduced from my star-charting. Nor was I then aware that Struve had followed up Piazzì’s hint in the introduction to the *Catalogus Regiomontanus*, and that he had been led to precisely my own conclusion,—viz., that the observed distribution of the stars of the leading orders of magnitude is incompatible with the accepted or textbook theory of the Sidereal System. Still less was I then aware, though I had carefully read through all Sir W. Herschel’s papers on the heavens, that in his later papers he virtually abandoned the theory of 1785. This fact had wholly escaped my notice, as I believe it escapes the notice of nearly all who give to those papers but a single perusal, however carefully that perusal may be made. It was only on a careful re-investigation of the whole series of Sir W. Herschel’s papers (well worth and indeed requiring many readings) that I observed how completely his views changed some fifteen years or so after the enunciation of the theory of 1785. Somewhat later I found that Struve had been led, by a second reading of Herschel’s papers, to a similar conclusion. For, in his *Etudes d’Astronomie Stellaire*, in which he extended his statistical inquiries to stars down to the 9th magnitude, he remarks that he “had been chiefly led to this ulterior discussion by a re-examination (*une nouvelle étude*) of the memoirs of Sir W. Herschel,” which “has led me to the conviction,” he adds, “that my actual ideas respecting the Milky Way are only opposed to Herschel’s theory of 1785, but agree very well with the latter views (*sont extrêmement conformes aux vues postérieures*) of that great astronomer.”

The researches I am now dealing with may be regarded as an extension of Struve’s inquiry; only that whereas he employed a method of statistical research, I have preferred the method of actual charting to which I have adhered throughout these inquiries—whether I have dealt with stars or nebulae. I believe that star-charting, appealing as it does directly to the eye, and presenting not only general features, but those minor details

which the statistician is obliged to neglect, is well worth the increased labour which it involves.

In order that the bearing of the present inquiry on Struve's, as well as on the Herschelian star-gauges, may be rightly apprehended, it will be as well to note what Struve and the Herschels actually accomplished, the more so that mistaken notions are very prevalent on the subject.

For instance, with respect to the star-gaugings, the opinion is not uncommonly entertained that the whole sphere of the heavens was surveyed or gauged by the Herschels. Many persons seem unaware of the fact that such a survey would have been quite impracticable even though these great astronomers had been able and willing to give their whole time to the work. When we remember that the labour actually bestowed by the Herschels on their star-gaugings bore but a minute proportion to that which they bestowed on other and more difficult researches, we need not be surprised to find that the portion of the heavens actually gauged was exceedingly small compared with the whole surface of the celestial sphere. To afford an idea of the real extent of the Herschelian gauges, the following illustration may be employed:—If the whole surface of the celestial sphere be represented by the surface of an ordinary chess-board, then all the gauge-fields of Sir W. Herschel taken together (though 3400 in number) correspond to but about the fourth part of one of the squares; while the gauge-fields surveyed by Sir John Herschel, taken together, correspond to somewhat less than a fifth part of one of the squares. Again, all the stars actually counted by Sir W. Herschel during his star-gauging amounted to about 90,000; those counted by Sir John Herschel to about 70,000: in all about 160,000. Now Struve estimates the total number of stars visible with the Herschelian gauging telescopes at upwards of 20 millions; so that the number actually counted is less than the 120th part of those which would have come into view in a complete survey. To this I may add that Sir W. Herschel, speaking of his 3400 gauges, says that he regards them as “only an example to illustrate the spirit of the method.”

Struve's latest and most extensive series of inquiries was applied to a list of 31,085 stars occupying a zone of the heavens between  $15^{\circ}$  north and  $15^{\circ}$  south of the equator, covering, therefore, a space equal to about the fourth part of the celestial sphere. By a series of ingenious inquiries into the number of stars probably missed in various parts of this zone, Struve virtually increased the number of stars he dealt with from about 31,000 to about 52,000.

The method he then adopted in dealing with these stars was simply this: he divided the great equatorial zone over which they were spread into hours of right ascension, and compared the numbers of stars in these divisions. He regarded these numbers as fairly indicating the richness of star-distribution *round the equator itself, compressing (as it were) a zone  $30^{\circ}$  wide into an*

indefinitely thin equatorial ring. Finally, he converted this equatorial ring into an equatorial disc, by conceiving the stars of the various orders of magnitude to be distributed at corresponding distances from the centre of the celestial sphere.

With all respect for the eminent abilities of the great Russian astronomer, I venture to point out that there are very grave objections to his method of research. The spaces into which he divided the heavens were inordinately large: each, in fact, extending  $15^\circ$  in right ascension and  $30^\circ$  in polar distance. To take averages for divisions so extensive must surely be regarded as unsatisfactory.

Moreover, the Galaxy, regarded by Struve as a zone of stellar concentration, runs obliquely across his wide equatorial zone, a circumstance obviously tending to render his results less instructive than they might otherwise have been. He notes this himself in accounting for the absence in his statistical results of all signs of the division of the Galaxy.

Lastly, as the main result of Struve's inquiries was to exhibit the want of uniformity in stellar distribution *over* the equatorial zone, his assumption of a uniform distribution *in the plane of* the equatorial disc, must be regarded as venturesome in the extreme.

As respects the construction of the chart which I now have the pleasure of exhibiting to this Society,\* I need here say little, because I have elsewhere adverted to the points which seem of chief importance. I would note, however, that the pencilled divisions on this projection represent spaces on the sphere averaging in extent one 280th part, only, of those into which Struve divided his equatorial zone. Each space, also, was filled in, *not* according to the mere number of stars, but very carefully by an eye-draught from the corresponding space in Argelander's charts. That I might not be influenced by the natural tendency (as Sir John Herschel calls it) to "exaggerate any peculiarity which might at the moment seem a feature," each meridional sector,  $5^\circ$  wide, was covered over as soon as it was completed. The work when once commenced was carried on without intermission (except for rest and food), all other work being set aside. The necessity for this will be obvious when it is remembered that if the work had been left even for a few days only, the probability is that on returning to it I might have somewhat modified the scale of star-magnitudes, a circumstance which would have rendered all the work valueless. Even as it was, I found continual watchfulness necessary lest any change in the style of the work should be unwittingly admitted. It is not easy to work at a star-map for six or seven weeks in succession without

\* Owing to a mistake on the part of the frame-maker, the original chart was not exhibited at the Meeting. Mr. Brothers obligingly supplied the defect by exhibiting a negative 8 inches in diameter. The original chart (25 inches in diameter) will be shown at the next Meeting.



changing the style or character of the charting; and I found it quite impossible to complete the chart in less than six or seven weeks. In fact, it is only necessary to compute the time required for marking in the stars to see that the work could not readily be compressed into a shorter interval of time. At the moderate rate of one minute for ten stars, 32,400 minutes, or 540 hours would be required; but the time actually occupied amounted only to 400 hours. I was pleased to find that along the line in which the last day's work was brought up to the first day's, no signs of any change in the style of mapping could be noticed. Had the star-magnitudes been enlarged or diminished in the interval, a sharp line of demarcation would unquestionably have been recognisable. As it is, I think I may defy the acutest observer to determine along what radial line the work began and ended.

So much being noted, in order that the trustworthiness of the chart may be sufficiently established, I will now briefly sum up the results to which the careful study of the chart appears to lead.

In the first place, Struve's general conclusion that the stars of the first nine or ten orders of magnitude are more densely aggregated along the galactic zone is abundantly justified.\* But instead of a gradual increase of density such as his statistics suggested, we recognise in the chart a distinctly marked aggregation within those very regions of the heavens where the Milky Way is brightest to the eye. In other words, we have clear evidence that it is not towards a certain *zone* that the stars are gathered, but into those irregular cloudlike masses, those streams, projections, and interlacing branches which constitute the Milky Way, as it is actually presented on clear nights to our study.

Let me quote here—in correction of that account of the Milky Way which is too often presented in our text-books—the description which Prof. Nichol has given of that wonderful star region. “It is, indeed, only to the most careless glance,” he justly says, “or when viewed through an atmosphere of imperfect transparency, that the Milky Way seems a continuous zone. Let the naked eye rest thoughtfully on any part of it, and if circumstances be favourable, it will stand out rather as an accumulation of patches and streams of light of every conceivable variety of form and brightness; now side by side; now heaped on each other; again spanning across dark spaces, intertwining, and forming a most curious and complex net-work; and at other times darting off into the neighbouring skies in branches of capricious length and shape, which gradually thin away and disappear.”

\* It is to be noticed that Argelander's magnitudes differ from those employed by Sir John Herschel. According to the nomenclature of the English astronomer my chart includes all stars down to the eleventh magnitude inclusive.

It will be seen that the aspect of the star-groups in the chart accords in the most significant manner with this description.

I would note, next, a circumstance which at first somewhat surprised me. The densely crowded regions in the chart show certain very well-marked projections in *Perseus* and *Auriga*, on the northern side of the Galaxy. Sir John Herschel, in his account of the Milky Way, mentions no such projections. But something in the aspect of these projecting masses seemed familiar to me so soon as I studied the complete chart. At length I was led to examine the Milky Way as depicted in the maps constructed by Sir John Lubbock. In my Gnomonic charts I had followed that figure of the Galaxy, and I had used the same delineation in a work now out of print, called the *Constellation Seasons*. On turning to my own drawings in these works, I found the very projections whose appearance had seemed familiar to me, as well as a long projection on the southern side of the Milky Way in *Perseus*, extending from *Algol* towards *Andromeda*. This projection also follows the direction of a declination-parallel, and its form is very clearly to be recognised in the chart. In the key-map I have shown these projections on opposite sides of the Milky Way in *Perseus*.

In the chart, however, we see these projections carried much further away from the main branch. We see, also, that from the other half of the Milky Way between *Cepheus* and *Aquila* there are similar extensions curving round on the northern side to a considerable distance from the main branch. One of these traverses *Lyra* and curves round almost to *Ursa Major*; another passes round from *Hercules* to *Corona*; while we note that the discontinuous branch which the naked eye recognises as extending from *Cygnus* to *Ophiuchus* is carried round towards *Boötes*.

Amongst these branching extensions there is, in places, so singular a tendency to agreement with declination-parallels, that the question may well suggest itself whether the peculiarity is not due to some feature in the construction of the maps—some bias, as it were, by which I might have been led to parallelize the star-grouping in this particular way; for plainly the north pole of the sky has no relation whatever to the construction of the stellar heavens. I am able to assert, however, with the utmost certainty of conviction, that nothing in the construction of the maps can explain the peculiarity. The original chart was most carefully divided into 26,400 spaces, each very small therefore, and the average number of stars to each space was but eighteen. These spaces were severally much smaller, both in length and breadth, than the cross-section of these branching extensions; so that even the most unpractised draughtsman, working in the most careless manner, could not have been so biassed that these curved branches could be thus explained away. As I have had some degree of practice in star-charting, and as, further, every portion of this chart was drawn as though it were forthwith to be subjected to the severest and most critical scrutiny, it will be understood how

utterly impossible it is that so marked a peculiarity can have the imagined explanation.\*

Apart from this, the curved branches will be found, on a close scrutiny, not to agree exactly with the direction of declination-  
parallels; and all of them can be traced in Argelander's large charts, when these are carefully studied.

A circumstance of some interest is to be recognised in the fact that these branching extensions are found to lead, in almost every instance, towards regions of the heavens where many nebulae exist.

The rich stellar region of *Orion*, as well as the *Hyades* and *Pleiades*, are shown to be intimately associated with the Milky Way.

In conclusion, I may remark that although the results to which this chart seems to point may appear altogether opposed to accepted views respecting the construction of the heavens, they accord exceedingly well with the enlarged views formed by Sir W. Herschel towards the close of his career as an observer,† and even better with the views towards which his later researches pointed. The mode of research I have adopted is altogether new, and it is one which seems more likely to lead to clear views of the construction of the heavens than any yet employed; for it presents before the eye at one view what hitherto has had to be inferred from tabulated figures. It is capable of a far wider extension, however; and I could wish that others who have more leisure than I can afford would aid in this interesting branch of inquiry. To such I would repeat the words by which Sir John Herschel, two years ago, encouraged me to fresh inquiries: "Be not deterred," he wrote on August 1, 1869, "from dwelling closely and consecutively on these inquiries, by any idea of their hopelessness which the objectors against 'paper astronomy' may entertain, or by the real slenderness of the material threads out of which any connected theory of the universe has at present to be woven."

Brighton, 8 Nov. 1871.

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*Extract of a Letter from E. J. Stone, Esq., to the Astronomer Royal, dated Royal Observatory, Cape of Good Hope, Sept. 30, 1871.*

"I had hoped to have been able to forward the Catalogue for 1858 and 1859 by this mail, but my work has been nearly stopped through illness [of some of the Assistants]. The year 1859 is much richer in Southern stars than the other years. I hope to have the years 1857, 1858, and 1859 ready for press within a month."

\* This does not preclude the possibility that there may be in places a tendency to "meridional" or "parallel" *graining*, so to speak; but of a much finer nature than the peculiarity referred to in the text, and in no way affecting the chart's real significance.

† I except the papers of 1817 and 1818.